論文の内容の要旨

Research of Processing Methods for Overlapped Neural Spikes using Bayesian Statistics
(ベイズ推論を用いたオーバーラップを含む神経信号の処理手法に関する研究)

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Overlapping of spike waveforms is a major problem in the detection and sorting of extracellularly recorded neural spikes because the original spike waveforms can become hidden and merged due to overlapping. Previous methods proposed for solving this problem include using a multitrode or placing a restriction on spike patterns. In the thesis, we proposed two methods to detect and sort arbitrarily overlapped spikes in order to help to obtain more accurate analyses of highly synchronized neural activity.

First, we propose a fast sequential method that can robustly detect and sort arbitrarily overlapped spikes recorded with arbitrary types of electrodes. In our method, the probabilities of possible spike trains including ones with overlapping are evaluated by a sequential Bayesian inference based on probabilistic models of spike-train generation and extracellular voltage recording. We derived a computationally efficient sequential Bayesian inference algorithm based on these models that is used to calculate the probability of spike existence at each sampling time in real-time. In addition, the “look-ahead probability", the probability calculated with the data for a few sampling times ahead, results in more efficient calculation. We assessed the performance of our method with simulated neural signals and a real neural signal recorded from primary cortical neurons cultured on a multi-electrode array. Our results showed that our method could be applied in real-time and the delay was less than 10ms. Furthermore, the estimation accuracy was higher than that of a conventional spike sorting method, especially for signals with many overlapped spikes.

Second, a method for simultaneous estimation of spike templates and timings of highly-overlapped spikes was proposed and the performance was assessed using simulated and real neural signals. In our method, the inference based on the hidden Markov model with the probabilistic penalty is efficiently calculated with the approximation. As the result, it was showed that our method could appropriately decompose the simulated and real signals containing complexly overlapped spikes.

Last, we applied two methods in combination to various data and compared the traditional approach and the application without the combination. The strong and weak points of these two methods are complementary and the procedure using two methods in combination performed better than other methods and applying without combination.